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The theoretical values of the annual mean motions, given in the paper, and there numbered (i), are

$$+146\ 435''\cdot3 \pm 1''\cdot8, \qquad -69\ 679''\cdot5 \pm 1''\cdot1.$$

The corrections examined above are therefore

$$-0''\cdot7, \qquad +0''\cdot2\,;$$

making my theoretical values

$$+146\ 434''\cdot6 \pm 1''\cdot8, \qquad -69\ 679''\cdot3 \pm 1''\cdot1.$$

The former is now quite close to the corrected value of Hansen—that previously numbered (iv)—which is 146 434″·9. The difference from the observational value is now 1″·0, but, as I remarked before, no argument can be based on this. The argument in the case of the node is quite unaffected; the error of 2″·0 in Hansen's theoretical result remains.

Haverford College, Pa.:
1897 *May* 1.

On some Spectroscopic Determinations of Velocity in the Line of Sight made at the Cambridge Observatory. By H. F. Newall.

The present note gives some results recently obtained in determinations of velocity in the line of sight with the Bruce spectroscope attached to the 25-inch refractor (the Newall telescope) of the Cambridge Observatory (*Monthly Notices*, lvi. p. 98).

The instrument was used for determinations of velocity and for the careful study of a few spectra throughout the year 1896; but on account of more or less systematic differences between the results obtained from the photographs and the results obtained by Dr. Vogel at Potsdam, it was necessary to subject the instrument to an even more searching investigation than it received in the course of the first adjustment. The difficulty has been the setting of the comparison spectrum, and the investigation has been of a very troublesome kind, as has already been indicated in the annual reports (see present vol. *Monthly Notices*, p. 250). The instrument is now apparently in excellent adjustment. The test photographs are completely satisfactory, and moreover the velocities deduced for several bright stars are in good agreement with those deduced by Dr. Vogel from photographs taken with the Potsdam spectrograph.

The cause of the systematic discrepancies above referred to has been discovered. A minute deflection of the collimator had been produced every time the comparison prisms were used. The deflection was traced to a deformation of a plate at the end of the strong frame of the spectroscope, brought about by altera-

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tions in the pressure of a spring attached to it. It may be stated that the observed discrepancies in the determination of velocity—amounting to about 20 kilometres per second—would be accounted for by a movement of the slit of the spectroscope through about 7 thousandths of a millimetre. The deflection produced a shift of the lines in the comparison spectra relatively to the corresponding lines in the star spectrum. The unexpected position of the strain made it very difficult to trace, and the search was made all the more difficult by the fact that the effect was variable in magnitude.

The velocities quoted in the following table as examples of results recently obtained must not be regarded as more than provisional except in the case of α *Boötis.* More photographs are needed

α *Tauri.*

Plate C. 411. 1897 March 4, $9^h\ 48^m$. Exposure 30 minutes.

Temperature 4°·7 to 4°·1 C.

Wave-length of line.	Velocity deduced relative to Earth.
λ4308	+87·2
4326	+88·4
4384	+78·3
4405	+64·2
4415	+75·7
Mean ...	+78·8
Correction for Earth's orbital velocity ...	−29·6
Velocity relative to Sun	**+49·2** kilometres per second.

[Vogel +47·6; Scheiner +49·4.]

α *Orionis.*

Plate C. 408. 1897 March 3. Exposure 55 minutes.

Wave-length of line.	Velocity deduced relative to Earth.
λ4315	+29·3
4370	+49·5
4405	+37·3
4415	+37·4
Mean ...	+38·4
Correction for Earth's orbital velocity ...	−27·8
Velocity relative to Sun	**+10·6** kilometres per second.

[Vogel +15·6; Scheiner +18·8.]

a Canis Minoris

(2 plates, 5 lines on each).

(1) Plate C. 405. 1897 Feb. 17, 12^h 10^m. Exposure 36 minutes.

Wave-length of line.	Velocity deduced relative to Earth.
λ4261	− 3·6
4308	+ 13·3
4384	+ 23·3
4405	+ 14·8
4415	+ 16·3
Mean ...	+ 12·8
Correction for Earth's orbital velocity ...	− 16·3
Velocity relative to Sun	− 3·5 kilometres per second.

(2) Plate C. 409. 1897 March 3, 10^h 54^m. Exposure 33 minutes.

Wave-length of line.	Velocity deduced relative to Earth.
λ4261	+ 7·9
4308	+ 17·0
4384	+ 14·8
4405	+ 17·9
4415	+ 25·2
Mean ...	+ 16·6
Correction for Earth's orbital motion ...	− 21·5
Velocity relative to Sun	− 4·9 kilometres per second.

[Vogel − 7·9; Scheiner − 10·5.]

β Geminorum.

(1 plate, 5 lines).

Plate C. 414. 1897 March 19, 9^h 53^m. Exposure 45 minutes.

Wave-length of line.	Velocity deduced relative to Earth.
λ4261	+ 22·8
4308	+ 28·0
4384	+ 23·5
4405	+ 28·9
4415	+ 29·3
Mean ...	+ 26·5
Correction for Earth's orbital motion ...	− 27·2
Velocity relative to Sun	− 0·7 kilometre per second.

[Vogel + 1·9; Scheiner + 0·4.]

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γ Leonis, bright component

(2 plates, 3 lines each).

(1) Plate C. 419. 1897 March 24, 10^h 47^m. Exposure 90 minutes.

Wave-length of line.	Velocity deduced relative to Earth.
λ4261	−21·7
4405	−25·4
4415	−28·8
Mean ...	−25·3
Correction for Earth's orbital motion ...	−17·0
Velocity relative to Sun	−42·3 kilometres per second.

(2) Plate C. 423. 1897 April 10, 11^h 13^m. Exposure 61 minutes.

Wave-length of line.	Velocity deduced relative to Earth.
λ4370	−13·0
4405	−20·2
4415	−10·0
Mean ...	−14·4
Correction for Earth's orbital velocity ...	−23·1
Velocity relative to Sun	−37·5 kilometres per second.

[Vogel −36·5; Scheiner −40·5.]

Test Photographs.

Diffused Sunlight from Cloud.

(1) Plate C. 407*d*. 1897 March 2.

Wave-length of line.	Velocity deduced relative to Earth.
λ4261	−7·6
4272	+1·7
4308	+1·3
4384	−6·7
4405	+0·2
4415	−0·7
Mean ...	−1·9 kilometre per second.

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(2) Plate C. 419*a*. 1897 March 27.

Wave-length of line.	Velocity deduced relative to Earth.
λ4261	−1·2
4308	+5·8
4326	−0·6
4384	−0·6
4405	+1·8
Mean	... +1·0 kilometre per second.

The velocity of α *Boötis* has been determined also by Belopolsky and Keeler, and accordingly this star was selected for special study, and the results are given in the table on page 573.

In taking the photographs, the following procedure is adopted. The slit is set parallel to the direction of daily motion and is partly covered by suitable diaphragms, which are movable, so that parts of the slit may be covered or exposed at the will of the observer. An electric spark between iron points is used as the terrestrial source of light for the comparison spectrum. First two exposures are made for the spectrum of iron; next the star spectrum is taken; and after the exposure for the star, two more exposures are made for the iron. Thus five spectra are set side by side on the one plate.

Iron taken before the star
Iron taken after the star
Star spectrum
Iron taken before the star
Iron taken after the star

The outer iron spectra are used for adjusting the wire of the micrometer to parallelism with the lines in the spectrum, the wire being set to bisect a line in the pair of spectra taken either before or after the star spectrum. The measurements are made only on the two inner iron spectra and on the star spectrum. The width of the five spectra is so small, that the curvature of the lines is not appreciable—an advantage largely due to the fact that only one prism is used. The width of the star spectrum is about 0·4 millimetre, and this is attained when the star-trail backwards and forwards along the slit amounts to about 0·2 millimetre.

The light from the spark passes into the slit after being reflected three times by reflecting prisms, and after passing through a lens. That satisfactory results are obtained from the

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use of a spark situated off the *real* axis of the collimator is attributed in part to the convenience of the reflecting slit (Dr. Huggins's arrangement), by which the observer is enabled to see the image of the whole spark whilst it is being adjusted on the slit, and in part to careful adjustment of the reflecting prisms and to exceedingly careful focussing of the collimator.

The following method of focussing the collimator has been found by far the most satisfactory. The collimator is focussed first by visual observations, carried out according to Schuster's method, the whole aperture being used. Then a diaphragm is put on, consisting of an opaque card with a circular aperture half that of the collimator lens. The collimator of the Bruce spectroscope has an aperture of two inches. Hence the diaphragm lets a one-inch beam pass. A photographic plate is put into the camera of the spectroscope, and two exposures are made on the same plate, one being got when the one-inch beam passes through the thick part of the prism, the other when the one-inch beam passes through the thin part. If the collimator is properly focussed, there is no shift or displacement of the lines in the two spectra. The existence of shift is a sign that the collimator is not adjusted (assuming that the prism and lenses are not faulty). The rationale of the method is clear, and when the collimator has been focussed in this manner the definition of the photographs is very good over a very considerable range of spectrum; the aberrations due to unsymmetrical passage through the prism when the incident beam is not properly collimated being very noticeable. Moreover, when the collimator has been focussed in the way described, a slight maladjustment of the axis either of the pencil of starlight or of the pencil of iron-spark-light relative to the axis of the collimator appears to be of no importance.

The results obtained in the case of *α Boötis* are set forth in the following table. Entirely independent measurements have been made by myself (N.) and by my assistant, A. W. Goatcher (G.), from seven plates of *α Boötis* taken since the last alterations were made to the spectroscope.

The scale of the photographed spectra is such that one millimetre in the length of the spectrum corresponds to 20·8 tenth-metres in the neighbourhood of λ 4260 and to 24·2 tenth-metres in the neighbourhood of λ 4415. The microscope used in measuring the photographs has a magnifying power of 21, and the micrometer screw is an excellent screw by Cooke. The average value of a revolution of the micrometer head expressed in terms of kilometres per second is 385 km/sec.

The velocity of light has been taken as 3×10^5 km/sec, and the solar parallax adopted is 8″·838.

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α *Boötis.*

(7 plates).

Measurements made by N.

Plate. Date 1897.	C. 422. Apr. $8^{d}13^{h}$.	C. 424. Apr. $10^{d}13^{h}$.	C. 427. Apr. $14^{d}13^{h}$.	C. 428. Apr. $14^{d}13\frac{1}{2}^{h}$.	C. 429. Apr. $27^{d}12^{h}$.	C. 430. May $1^{d}12^{h}$.	C. 433. May $3^{d}13^{h}$.
λ4250·3	...	− 9·7	...	...	...	...	...
4250·9	...	− 3·9	...	...	...	...	...
4260·6	−21·2	−11·0	− 8·3	−16·1	+1·0	0·0	− 1·6
4308	− 8·0	− 2·1	+ 2·1	− 9·5	−4·0	−1·1	+ 7·8
4315	...	...	−11·9	...	...	...	...
4370	− 5·9	− 1·9	− 1·0	−12·3	...	−3·2	...
4384	−12·9	− 8·0	− 9·2	− 7·7	−6·6	...	...
4405	− 3·3	− 6·7	− 3·9	+ 0·8	−3·5	+8·2	+13·1
4415	− 6·7	− 3·3	+ 0·5	− 5·8	−3·0	+6·7	+13·8
4427	−15·4	− 2·8	+ 0·3	− 2·2	...	...	+10·4
Mean ...	−10·5	− 5·5	− 3·9	− 7·5	−3·2	+2·1	+ 8·7
Corr. to ⊙	+ 1·9	+ 1·0	− 0·7	− 0·7	−6·2	−7·9	− 8·7
Vel. rel. to ⊙	− **8·6**	− **4·5**	− **4·6**	− **8·2**	**−9·4**	**−5·7**	**0·0**
Prob. error	± 1·5	± 0·8	± 1·2	± 1·5	±0·8	±1·5	± 2·4

Mean for 7 plates − 5·9 ± 0·8 (N)

Measurements made by G.

λ4250·3	−13·8	−14·7	...	...	...	...	...
4250·9	...	− 3·1	...	...	...	...	...
4260·6	−17·4	−14·2	−13·3	−16·6	−3·7	0·0	− 3·5
4308	− 7·5	− 2·3	− 0·3	− 6·4	...	+2·8	+ 8·4
4315	...	...	−12·0	...	−4·0	...	...
4370	− 5·2	− 4·6	− 2·2	−14·2	...	...	...
4384	−20·6	− 9·0	− 6·9	− 7·7	−4·7	...	...
4405	−12·0	− 4·1	− 6·2	− 3·0	+0·2	+2·7	+ 7·1
4415	− 8·1	− 1·0	− 0·2	− 2·0	+0·5	+2·5	+11·5
4427	− 8·9	−16·1	− 4·0	− 0·3	...	...	...
Mean ...	−11·7	− 7·7	− 5·6	− 7·2	−2·3	+2·0	+ 5·9
Corr. to ⊙	+ 1·9	+ 1·0	− 0·7	− 0·7	−6·2	−7·9	− 8·7
Vel. rel. to ⊙	− **9·8**	− **6·6**	− **6·3**	− **7·8**	**−8·6**	**−5·9**	− **2·8**
Prob. error	± 1·3	± 1·3	± 1·2	± 1·6	±0·7	±0·5	± 2·2

Mean for 7 plates −6·8 ± 0·6 (G)

[Vogel **−7·0**; Scheiner **−8·3**; Belopolsky **−5·7**; Keeler **−6·8**.]

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The lines measured have been selected in the star spectrum from a great number of iron lines, on account of ease in identification. A comparison of the solar spectrum, as photographed with small dispersion, and as represented in Rowland's map, which has a dispersion about sixty-six times as great, shows that the iron lines are involved in groups, so that the choice of lines is practically decided by the predominance of an iron line amongst its immediate neighbours. The *group* is bisected in the photograph, but the bisection does not necessarily coincide with the true position of the iron line in the group. Consequently each line chosen will give a velocity which is affected with an error in identification. If enough lines are measured, these errors might be supposed to cut one another out. The discussion of the measurements of *α Boötis* will show what is to be expected. (See the table below.)

The determination of velocity from a single line is based on eleven micrometer settings—three on the iron line in the spectrum taken at the beginning of the exposure, and three on the iron line taken at the end, and five settings on the group which represents the iron line in the star spectrum. The difference between the means for the iron lines is the shift due to change of temperature or to change in the position of the instrument during the exposure. It is assumed that this change is a linear function of the time, and the displacement of the star line or group relative to the mean of the initial and final positions of the iron line is taken to get the velocity. The mean of about seven velocities deduced from as many lines in a plate is regarded as the velocity deduced from the plate.

It appears from the measurements that the probable error of the velocity determined from a single line (eleven micrometer settings), on the assumption of no error of identification, is between ± 0·2 and ± 0·6 km/sec according to the goodness of the photograph.

The probable error of the velocity deduced from about seven lines on a plate is between ± 0·5 and ± 1·5 km/sec, again assuming no errors in identification.

The probable error of the velocity deduced from seven plates is about ± 0·7, on the assumption that *α Boötis* has a constant velocity relative to the Sun, and is not a spectroscopic double-star.

With a view of seeing how far the velocity deduced from a given line on the seven plates would give evidence of a calculable error of identification, the mean velocity relative to the Sun for each of seven lines was got out.

The group of lines, which was bisected in the micrometer setting, was compared in each case with Rowland's map; and the attempt was made to form an estimate of the displacement of the centre of the group from the true centre of the iron line which predominated in the group, weight being given to the foreign lines involved in the group according to the intensity of

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the lines as recorded in Rowland's tables. This displacement was expected to be in a sense the error in identification of the true iron line in the star spectrum. The velocity corresponding to the displacement was then computed, and the results are entered in the last column of the table. The assumption underlying this, viz., that the spectrum of *a Boötis* is similar in detail to that of the Sun, appears to be supported by a comparison of the spectra.

	Velocity relative to Sun. N.	Velocity relative to Sun. G.	Residuals. N.	Residuals. G.	Computed Error of Identification.
λ4260·6	−11·0	−12·7	+5·4	+6·0	+7·7
4308	− 5·2	− 3·3	−0·5	−3·4	+5·6
4370	− 5·6	− 6·0	−0·1	−0·7	0·0
4384	− 9·0	−10·6	+3·3	+3·9	0·0
4405	− 2·7	− 5·1	−3·0	−1·6	+1·4
4415	− 2·8	− 2·5	−2·9	−4·2	−4·1
4427	− 3·7	− 6·8	−2·0	+0·1	+4·1
Mean ...	− 5·7	− 6·7 km/sec	Mean		... +2·5 km/sec

The material is in reality too slight for a completely satisfactory comparison; and yet as far as it goes, it affords means of estimating the errors involved in the use of small dispersion. One point is made clear by the investigation, viz. that little or no advantage, so far as the elimination of the error of identification is concerned, would be gained by *doubling* the dispersion and resolving power of the spectroscope; for the disturbing lines in the groups selected would not be separated from the iron lines without a considerably greater increase.

a Geminorum (Castor).

Two excellent photographs of the spectra of the components of *a* Geminorum were obtained in 1896 November, each having a spectrum of the faint star in the system between two spectra of the bright star. It was observed that (i.) the spectrum of the bright star was similar to that of *a Lyræ*; (ii.) the spectrum of the faint star resembled that of *a Cygni* very closely; (iii.) lines common to the two spectra showed considerable relative shift; (iv.) the shift of the lines in the faint star spectrum was towards the red in one photograph and towards the blue in the other.

The photographs have been measured with the following results:—

(1) Plate C. 382. 1896 Nov. 4, $13^h\ 35^m$ to $15^h\ 9^m$. Observer, N.

Exposures	Bright component	30 minutes.
	Faint ,, ...	50 ,,
	Bright ,, ...	12 ,,

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	Velocity of Faint relative to Bright.
λ4290	−50·3
4326	−35·2
4395	−41·1
4482	−41·8
4550	−43·0
Mean ...	−42·3 km/sec. (N)

(2) Plate C. 385. 1896 Nov. 5, $11^h\ 47^m$ to $13^h\ 14^m$. Observer, G.

Exposures	Bright component	25	minutes.
	Faint ,, ...	50	,,
	Bright ,, ...	10	,,

	Velocity of Faint relative to Bright.
λ4290	+28·9
4308	+29·6
4352	+37·1
4418	+32·3
4482	+23·0
4550	+33·8
Mean ...	+30·8 km/sec. (N)

These photographs were taken without any comparison spectra last autumn, before the cause of difficulty with the comparison spectra was found out; but it is clear that they are not open to the objection that has necessitated the rejection of results relating to the determination of velocity with the Bruce spectroscope before 1897 February. But as the cause of vitiation was not known, the large shifts observed in the spectra of *Castor* now dealt with were regarded with a suspicion that is now removed. The velocities deduced are, therefore, regarded as completely trustworthy.

Belopolsky has found (*Astrophysical Journal*, vol. v. p. 1, 1897) that the faint component of *Castor* is a spectroscopic binary, and that within a period of 2·91 days the velocity of the star relative to the Sun passes through a series of changes, ranging between +35 and −45 km/sec. Belopolsky has deduced as the time of periastron passage the date 1896 February 28·82 ± 2·91 *n*. Assuming this period, the interval since the preceding periastron passage for each of the photographs above referred to is given below; the corresponding velocities deduced from Belopolsky's orbit are also given. Assuming that the velocity (relative to the Sun) of the system α_1 (faint star and invisible companion) is the same as that of α_2 (bright

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star), then the observed velocities above recorded should be comparable with those computed from Belopolsky's data.

			$\frac{dz}{dt}$ *km/sec.*	Cambridge Obs.
C. 382	1896 Nov. 4·60	= 1896 Feb. 28·82 + ($2^{\mathrm{d}}{\cdot}91$ × 85) + $2^{\mathrm{d}}{\cdot}44$	+39	−42·3
C. 385	1896 Nov. 5·53	= 1896 Feb. 28·82 + (2·91 × 86) + 0·46	−39	+30·8

The photographs show a change of velocity quite comparable with that discovered by Belopolsky, but exactly opposite in phase. The period $2^{\mathrm{d}}{\cdot}91$ is not accurately enough known for the calculation of an ephemeris so far ahead as seven months. It would appear that an odd number of half periods has been lost or gained between April and November. Belopolsky's discussion of thirty-two photographs pointed to some possible variation in the period, and it is to be hoped that he has secured more evidence in the present year.

The photographs obtained at Cambridge, however, appear to support Belopolsky's most interesting discovery, that in the system of *Castor* two periods must now be recognised, one about 1000 years, the other probably less than three days.

On a New Binary Star with a Period of 5½ *Years* (β 883).

By T. J. J. See, A.M., Ph.D. (Berlin).

For several months I have been practically certain that the double star β 883 = Lalande 9091, $\alpha = 4^{\mathrm{h}}\ 44^{\mathrm{m}}\ 33^{\mathrm{s}}{\cdot}0$, $\delta = +10^{\circ}\ 52'$ (1875·0) is revolving in a period of about 5·5 years, and thus describing its orbit in less than one-half the time required for the most rapid system heretofore known; but it seemed desirable to withhold any announcement of such an extraordinary result until the observations should remove every reasonable doubt of the correctness of the conclusion. Indeed, this hypothesis first presented itself to my mind in the summer of 1895, when I was examining the orbits of all known binaries with a view to selecting those most accurately determined for incorporation into the work recently published (*Researches on the Evolution of the Stellar Systems*, vol. i.).

Professor Schiaparelli had very kindly communicated by private letter a number of his unpublished obvervations of this star, and on combining these with other measures in my possession it seemed clear that only a period of about 5·5 years would satisfy the observations. Professor Burnham, however, did not regard the evidence as conclusive, and I decided to wait till further measures were available. On entering upon the measurement of southern double stars I felt that notwithstanding the northern position of this object the great interest attach-